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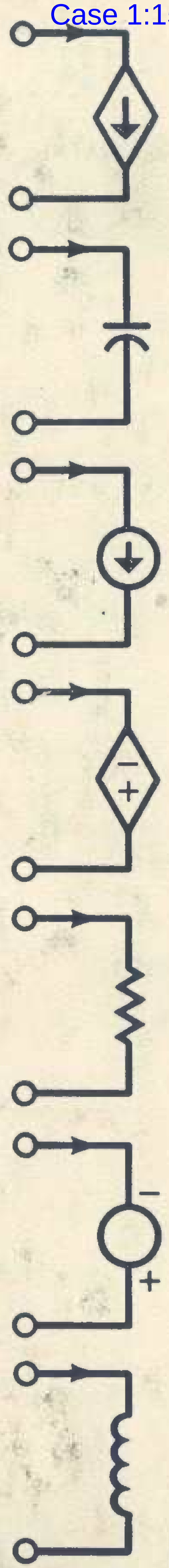

Basic Engineering Circuit Analysis

THIRD EDITION

J. David Irwin

3RD EDITION

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CHAPTER

2

Resistive Circuits

In this chapter we introduce some of the basic concepts and laws that are fundamental to circuit analysis. In general, we will restrict our activities to *analysis*, that is, to the determination of a specific voltage, current, or power somewhere in a network. The techniques we introduce have wide application in circuit analysis, even though we discuss them within the framework of simple networks.

2.1 Ohm's Law

Ohm's law is named for the German physicist Georg Simon Ohm, who is credited with establishing the voltage–current relationship for resistance. As a result of his pioneering work, the unit of resistance bears his name.

Ohm's law states that *the voltage across a resistance is directly proportional to the current flowing through it*. The resistance, measured in ohms, is the constant of proportionality between the voltage and current.

A circuit element whose electrical characteristic is primarily resistive is called a resistor and is represented by the symbol shown in Fig. 2.1. A resistor is a physical device that can be purchased in certain standard values in an electronic parts store. These resistors, which find wide use in a variety of electrical applications, are normally carbon-composition or wirewound. In addition, resistors can be fabricated using thick oxide or thin metal films for use in hybrid circuits, or they can be diffused in semiconductor integrated circuits.

The mathematical relationship of Ohm's law is illustrated by the equation

$$v(t) = Ri(t) \qquad \text{where } R \geq 0 \tag{2.1}$$

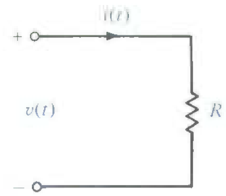


Figure 2.1 Symbol for the resistor.

or equivalently, by the voltage–current characteristic shown in Fig. 2.2a. Note carefully the relationship between the polarity of the voltage and the direction of the current. In addition, note that we have tacitly assumed that the resistor has a constant value and therefore that the voltage–current characteristic is linear.

The symbol Ω is used to represent ohms, and therefore

$$1\ \Omega = 1\ \text{V/A}$$

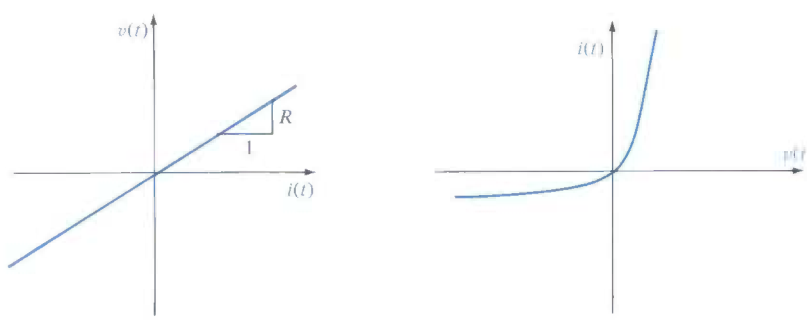
Although in our analysis we will always assume that the resistors are *linear* and are thus described by a straight-line characteristic that passes through the origin, it is important that readers realize that some very useful and practical elements do exist that exhibit a *nonlinear* resistance characteristic; that is, the voltage–current relationship is not a straight line. Diodes, which are used extensively in electric circuits, are examples of nonlinear resistors. A typical diode characteristic is shown in Fig. 2.2b.

Since a resistor is a passive element, the proper current–voltage relationship is illustrated in Fig. 2.1. The power supplied to the terminals is absorbed by the resistor. Note that the charge moves from the higher to the lower potential as it passes through the resistor and the energy absorbed is dissipated by the resistor in the form of heat. As indicated in Chapter 1, the rate of energy dissipation is the instantaneous power, and therefore

$$p(t) = v(t)i(t) \tag{2.2}$$

which, using Eq. (2.1), can be written as

$$p(t) = Ri^2(t) = \frac{v^2(t)}{R} \tag{2.3}$$



(a) (b)

Figure 2.2 Graphical representation of the voltage–current relationship for (a) a linear resistor and (b) a diode.

This equation illustrates that the power is a nonlinear function of either current or voltage and that it is always a positive quantity.

Conductance, represented by the symbol G, is another quantity with wide application in circuit analysis. By definition, conductance is the inverse of resistance: that is,

$$G = \frac{1}{R} \tag{2.4}$$

The unit of conductance is the siemens, and the relationship between units is

$$1 \text{ S} = 1 \text{ A/V}$$

Using Eq. (2.4), we can write two additional expressions,

$$i(t) = Gv(t) \tag{2.5}$$

and

$$p(t) = \frac{i^2(t)}{G} = Gv^2(t) \tag{2.6}$$

Equation (2.5) is another expression of Ohm's law.

Two specific values of resistance, and therefore conductance, are very important: $R = 0$ and $R = \infty$. If the resistance $R = 0$, we have what is called a *short circuit*. From Ohm's law,

$$\begin{aligned} v(t) &= Ri(t) \\ &= 0 \end{aligned}$$

Therefore, $v(t) = 0$, although the current could theoretically be any value. If the resistance $R = \infty$, we have what is called an *open circuit*, and from Ohm's law,

$$\begin{aligned} i(t) &= \frac{v(t)}{R} \\ &= 0 \end{aligned}$$

Therefore, the current is zero regardless of the value of the voltage across the open terminals.

EXAMPLE 2.1

In the circuit shown in Fig. 2.3a, determine the current and the power absorbed by the resistor.

Using Eq. (2.1), we find the current to be

$$I = \frac{V}{R} = \frac{10}{2} = 5 \text{ A}$$

and from Eq. (2.2) or (2.3), the power absorbed by the resistor is

$$\begin{aligned} P &= VI = (10)(5) = 50 \text{ W} \\ &= RI^2 = (2)(5)^2 = 50 \text{ W} \\ &= \frac{V^2}{R} = \frac{(10)^2}{2} = 50 \text{ W} \end{aligned}$$